Integration of Energy and Water Cycle Research Products in a Global Land Surface Modeling and Assimilation System

P.I. Matt Rodell (NASA/GSFC)
Co-Is Christa Peters-Lidard (NASA/GSFC), Rolf Reichle (UMBC/GEST), Sujay Kumar (UMBC/GEST), Jesse Meng (UMBC/GEST), and Richard Kelly (UMBC/GEST)

Project hypothesis: Large scale land surface processes cannot be skillfully represented and described without a comprehensive approach, which integrates the best water and energy cycle observations as data for parameterizing, forcing, constraining, and evaluating sophisticated land surface models (LSMs).

Objectives & deliverables:

- Implement mature assimilation capabilities within LIS, including schemes for assimilating AMSR soil moisture (e.g., Zhan et al., 2004) and snow water equivalent (e.g., Sun et al., 2004), MODIS snow cover (e.g., Rodell and Houser, 2004), and geostationary satellite IR surface temperature (e.g., Bosilovich et al., 2004; Radakovich et al., 2001)
- Incorporate new data products developed by the NEWS team
- Utilize runoff routing and a coupled boundary layer model
- Include subgrid precipitation variability
- Assess impacts/interactions of new datasets and capabilities
- Produce long term, global LSM analyses and associated uncertainty assessments, using multiple configurations with each of the linked LSMs

Objectives & deliverables (continued):

- Distribute output through a public, web-based interface
- Characterize regional, seasonal to interannual variability in the stocks and fluxes of the water and energy cycles
- *We envision our modeling and data assimilation system as being a tool for NEWS research, hence project objectives will be guided largely by the needs of the NEWS team.*

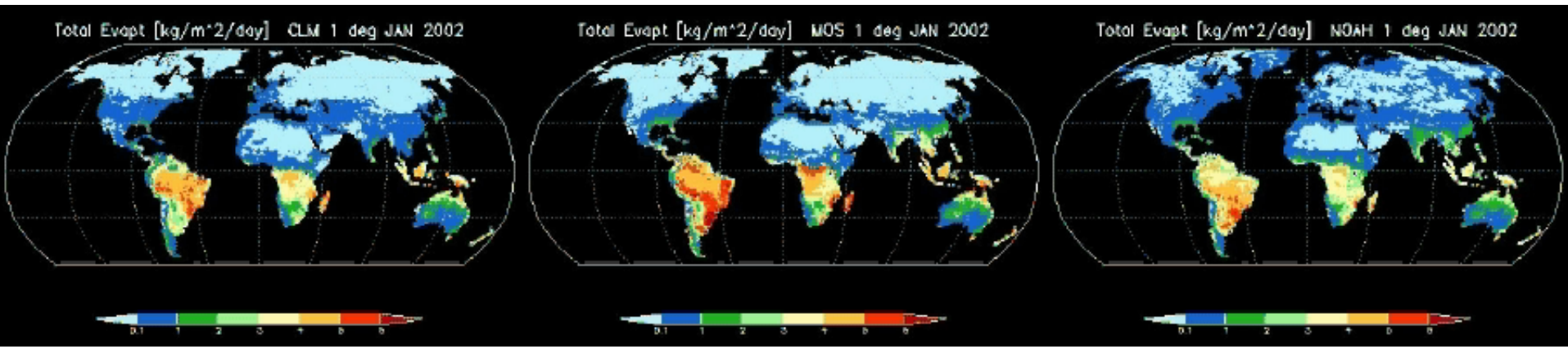
Technical approach and/or methods (can be supported or explained with 2-3 additional figure pages):

- Integration of datasets and capabilities within the framework of the Land Information System (LIS)
- INTERCOMPARISON and OPTIMAL MERGING of global data fields
- Satellite data products used to PARAMETERIZE and FORCE sophisticated land surface models
- ASSIMILATION of satellite based land surface state fields (snow, soil moisture, surface temp, etc.)
- Ground-based observations used to EVALUATE model output

Background: GLDAS

GLDAS = Global Land Data Assimilation System

- IDS project 2000-03, THP extensions 2004, 2005
- Based on North American LDAS
- Includes massive archive of land surface and met datasets
- Adopted LIS software in 2003
- Available output includes 0.25° and 1° global, 1979-present simulations with 3 LSMs: CLM, Mosaic, and Noah
- http://ldas.gsfc.nasa.gov/ ; Rodell et al., BAMS, 2004

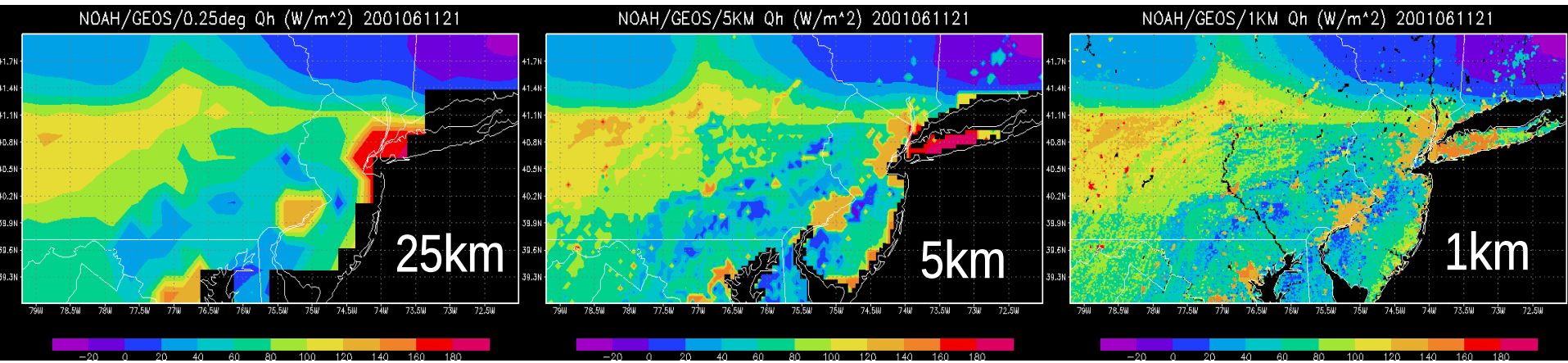


Monthly mean evapotranspiration, 2002-04, from simulations with CLM2, Mosaic, and Noah 2.7.1 LSMs. [Color bars range from 0.1 to 8 mm/day]

Background: LIS

LIS = Land Information System

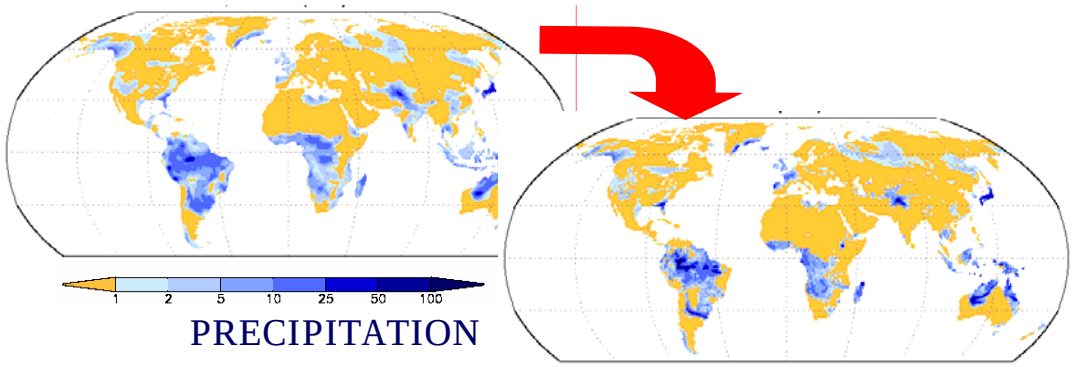
- HPCC project 2002-05
- Based on GLDAS
- Highly efficient, parallel, modular software enables 1 km resolution, global land surface model simulations
- ESMF and ALMA standard compliant
- 2005 NASA Software of the Year Award winner
- http://lis.gsfc.nasa.gov/ ; Kumar et al., Environ. Mod. Software, 2005

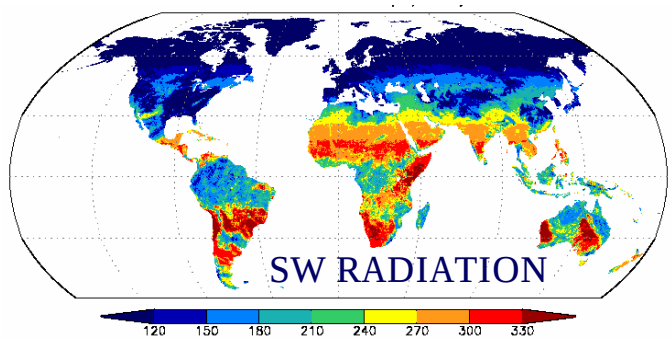


Sensible heat flux, 21Z 11 June 2001, from 0.25°, 5 km, and 1 km resolution Noah simulations [Color bars range from -20 to 180 W/m^2]

Product Integration

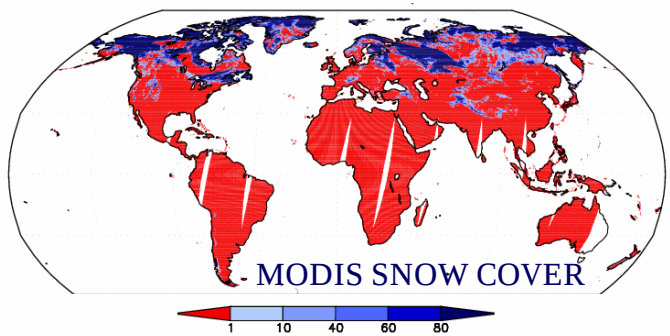
INTERCOMPARISON and OPTIMAL MERGING of global data fields

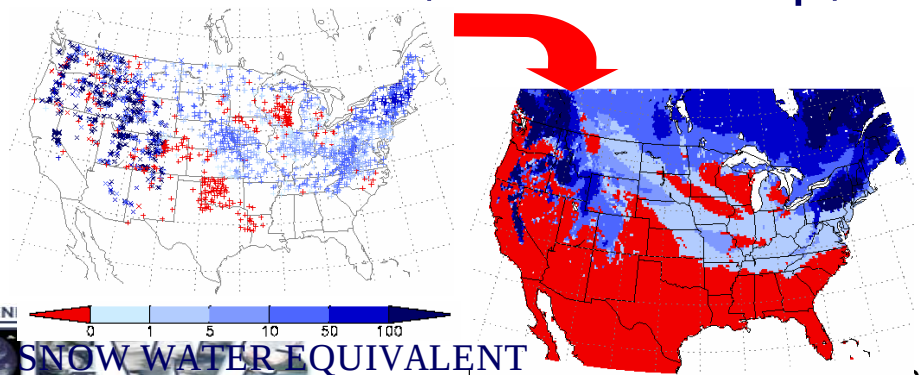




Satellite data products used to PARAMETERIZE and FORCE sophisticated land surface models

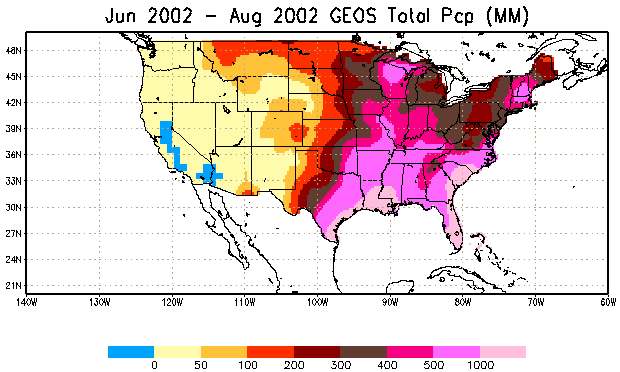
ASSIMILATION of satellite based land surface state fields (snow, soil moisture, surface temp, etc.)

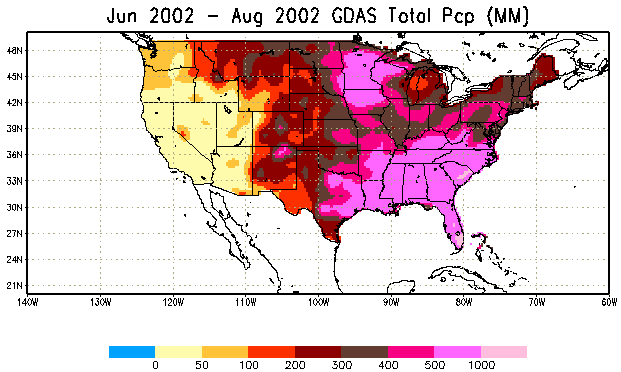


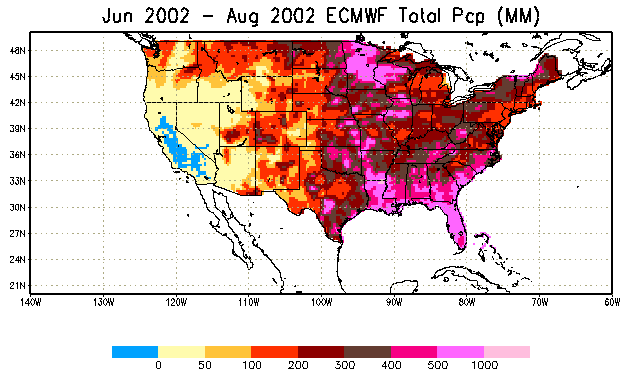


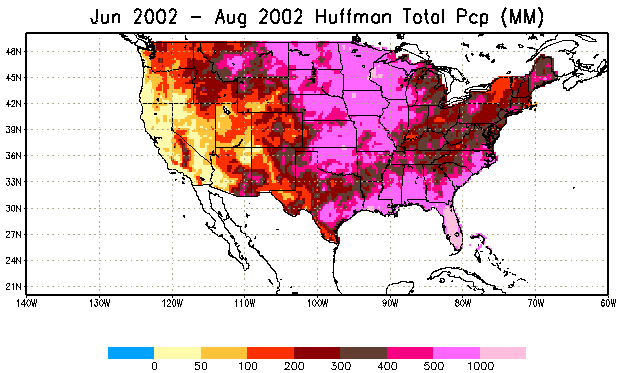
Ground-based observations used to EVALUATE model output

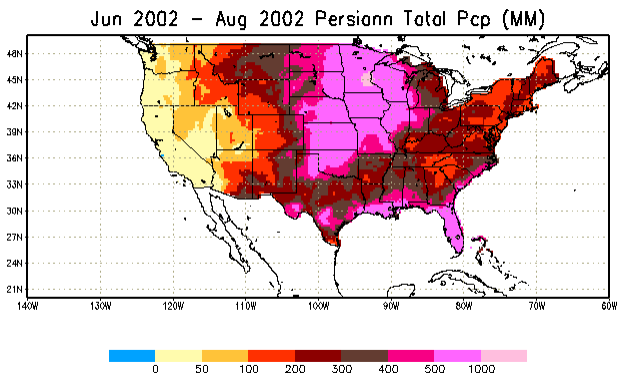
Intercomparison of Data Fields: Precipitation

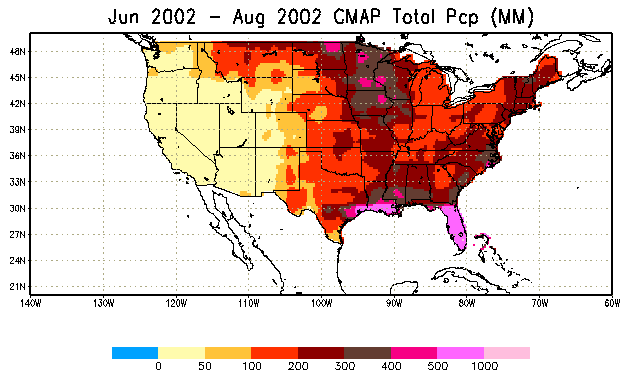


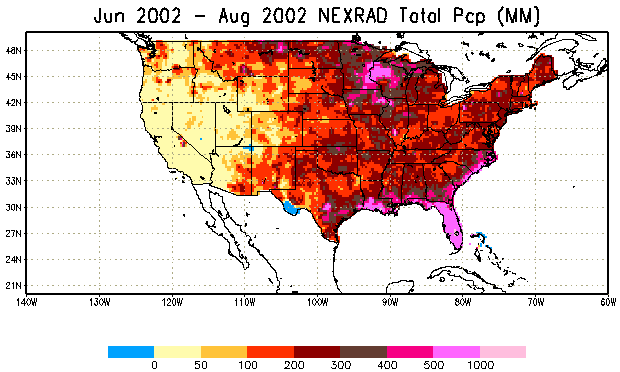




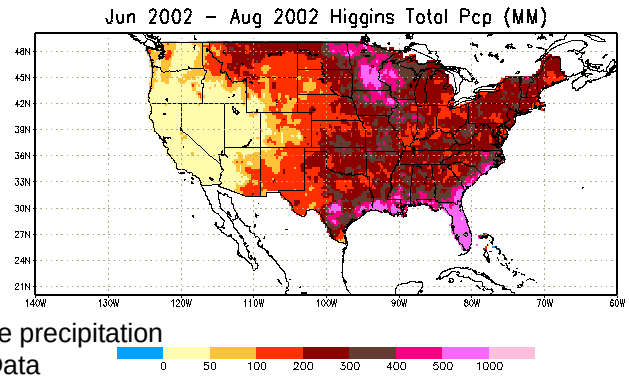






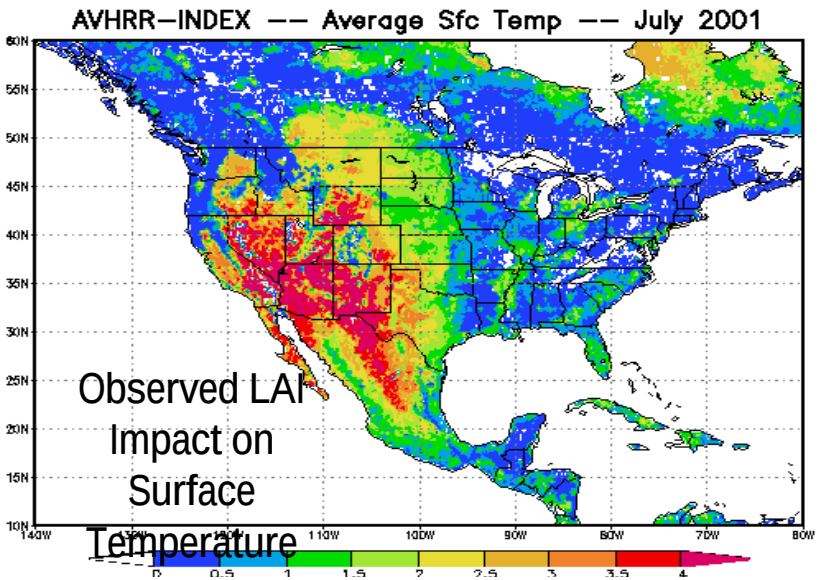


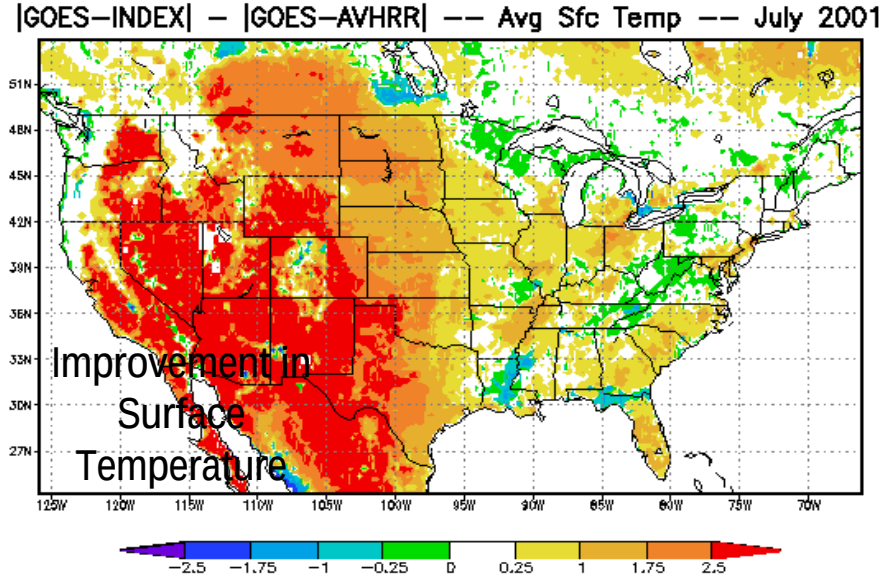
Accumulated Precipitation, JJA 2002

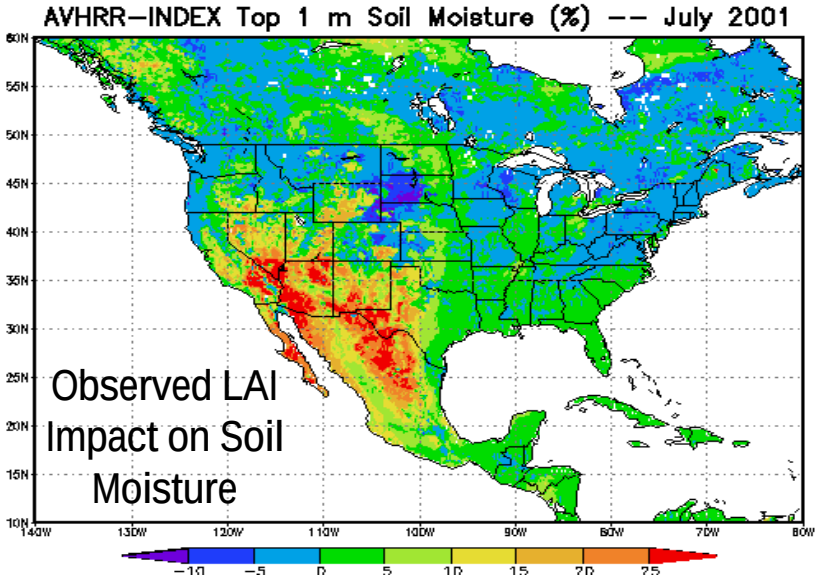


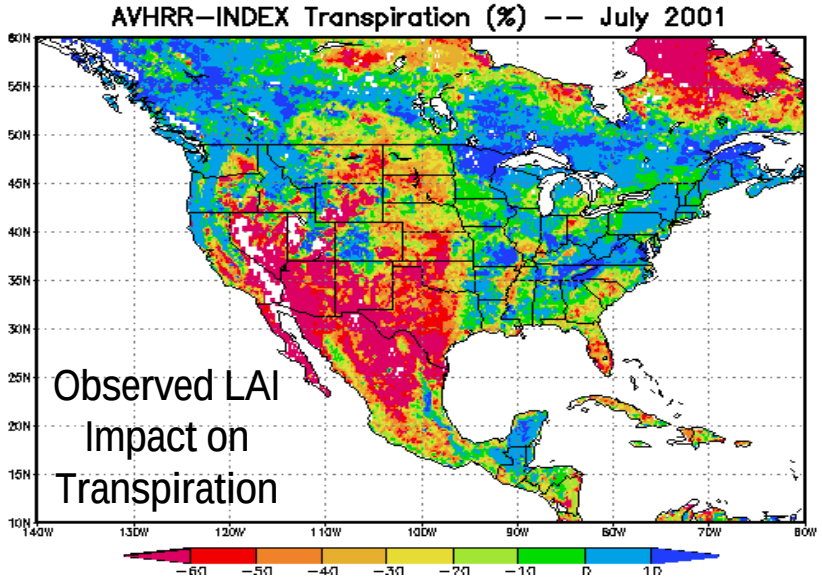
Gottschalck, J., J. Meng, M. Rodell, and P. Houser, Analysis of multiple precipitation products and preliminary assessment of their impact on Global Land Data Assimilation System (GLDAS) land surface states, J. Hydromet., in press, 2005.

Parameterization: Leaf Area Index



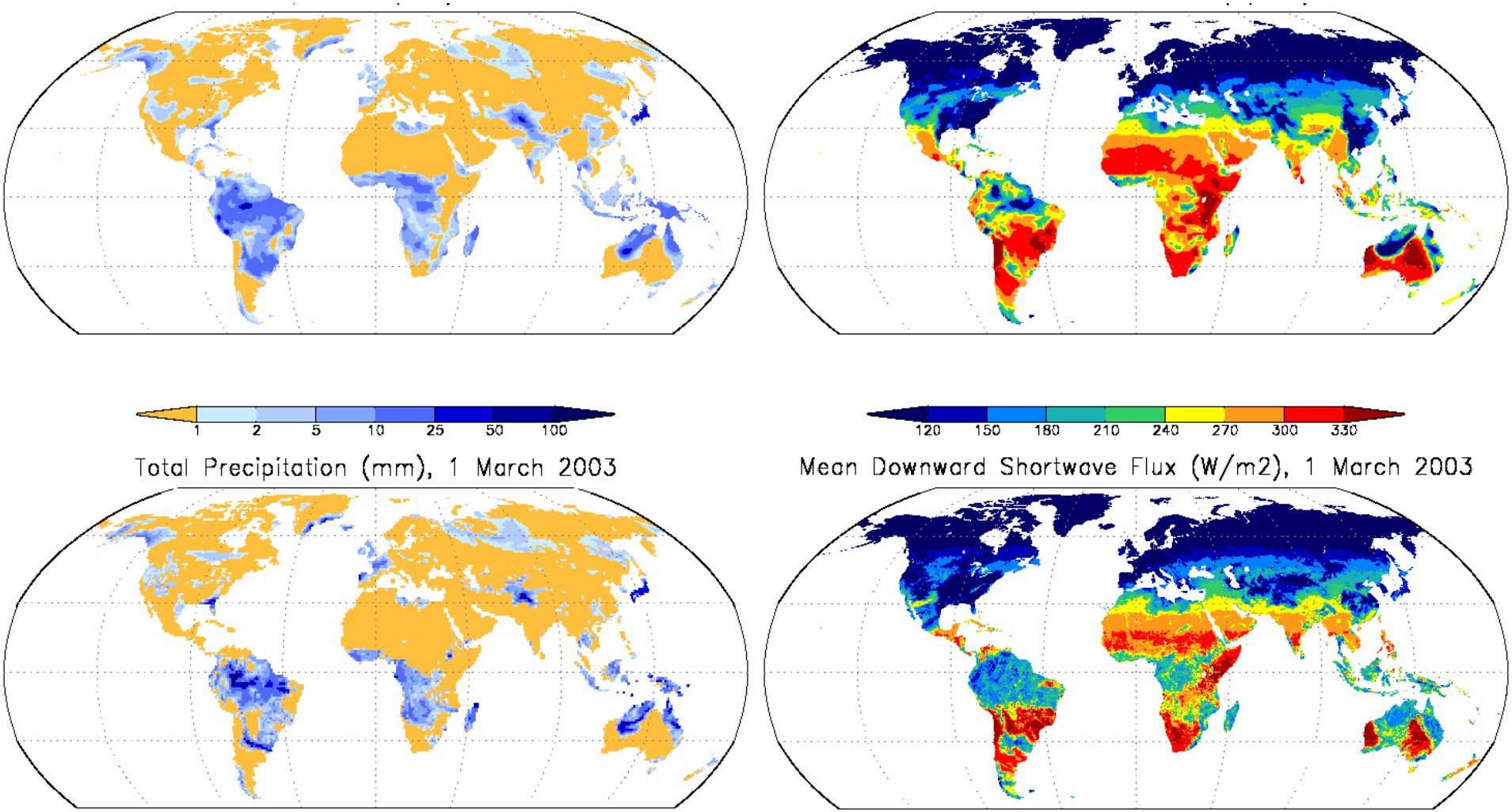






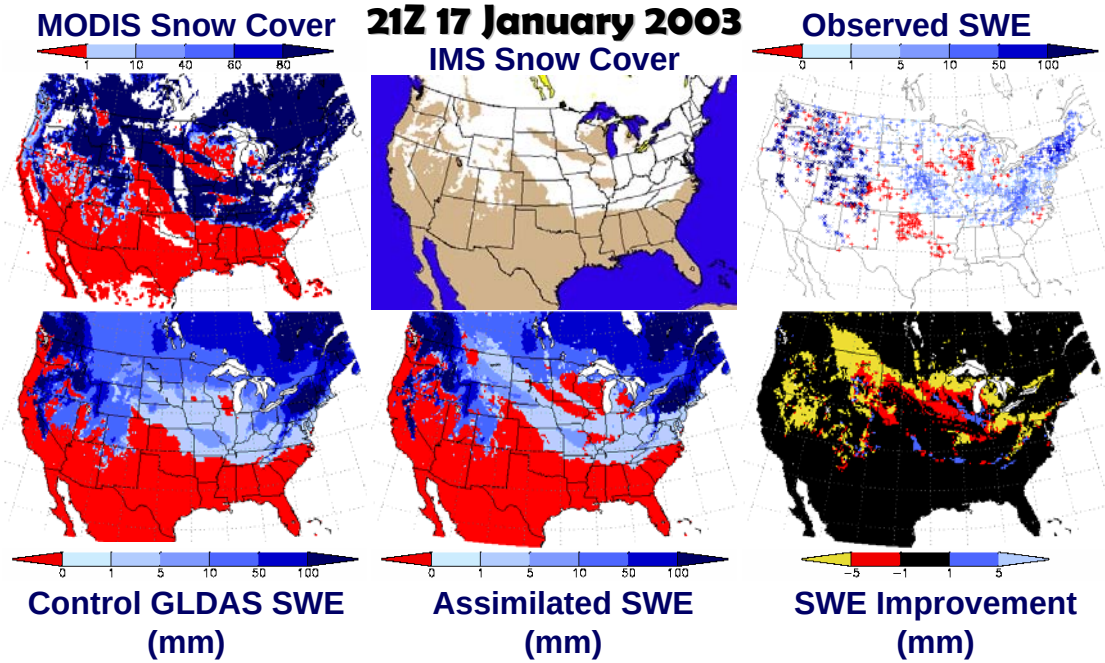
Gottschalck, J., M. Rodell, P. Houser, U. Jambor, J. Meng, K. Arsenault, and B. Cosgrove, Impact of remotely sensed leaf area index as part of the Global Land Data Assimilation System, J. Hydromet., submitted, 2005.

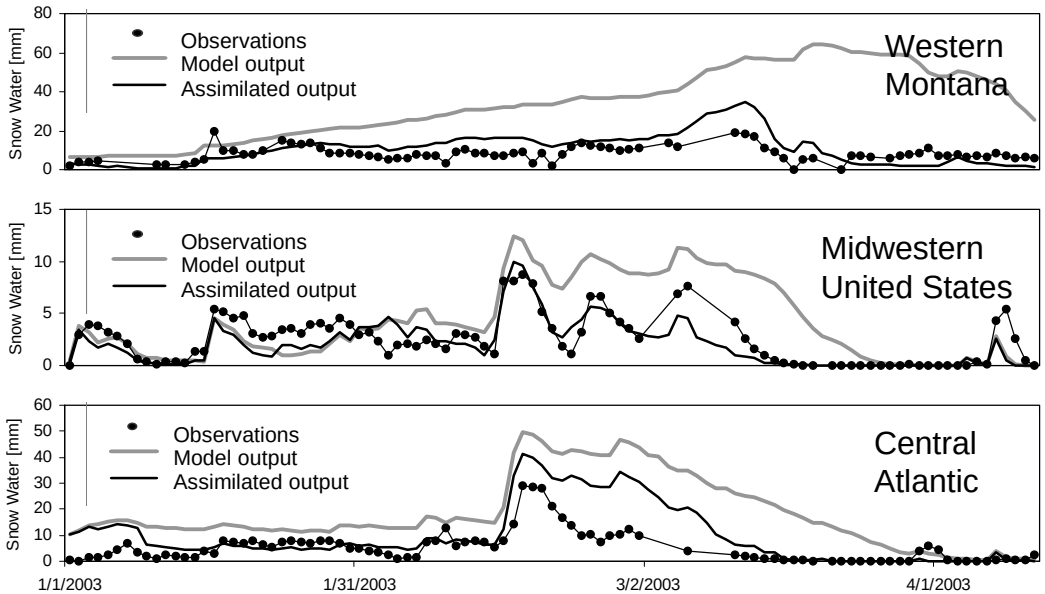
Forcing: Observation vs. Model Based



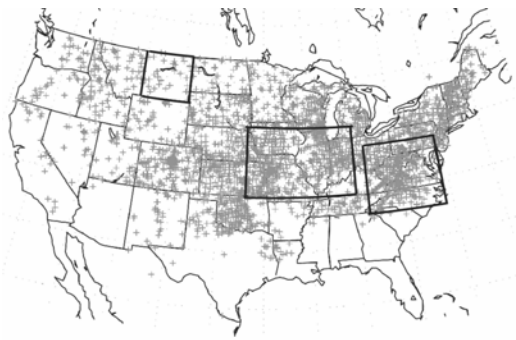
Precipitation (left) and downward shortwave radiation (right) from the GEOS atmospheric DAS (top) and GLDAS merged forcing products: disaggregated CMAP (bottom left) and AGRMET (bottom right)

Data Assimilation: Snow





- **MODIS snow cover fields used to update GLDAS simulations**
- **Models fill spatial and temporal gaps in data**
- **Assimilated output agrees more closely with independently derived snow fields (top left) and time series (bottom left)**
- **Assimilated output contains more information (snow water equivalent) than MODIS (snow cover) alone**

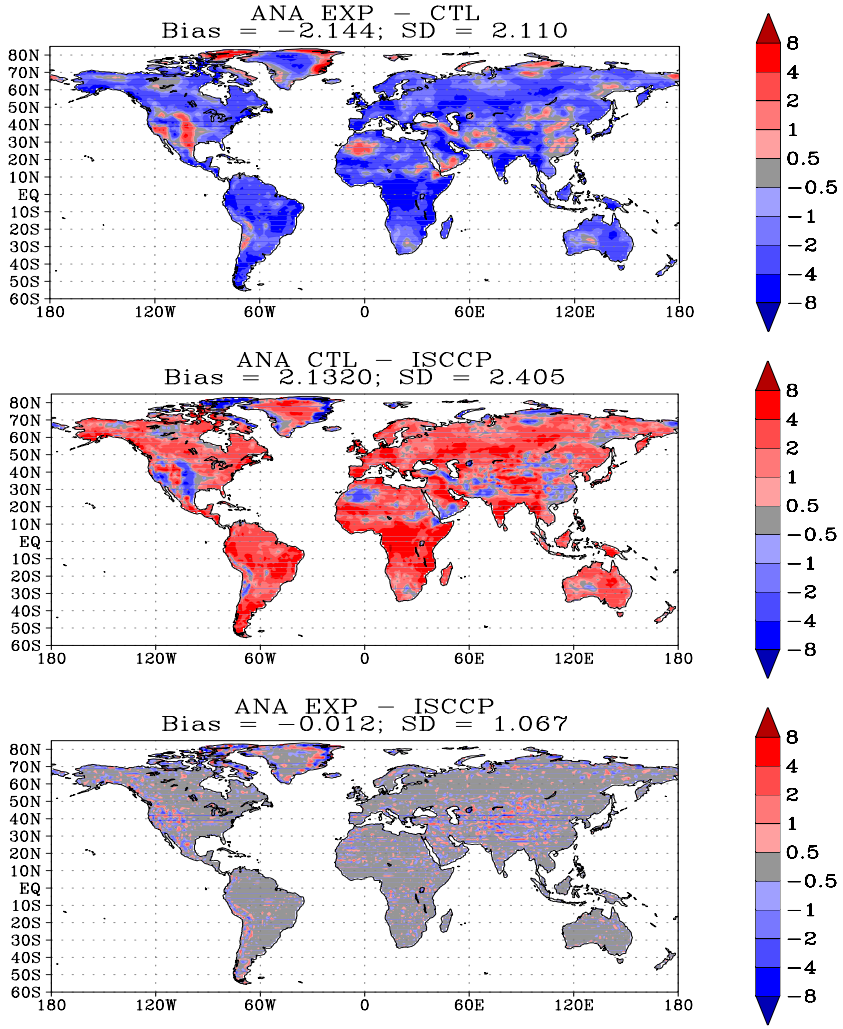


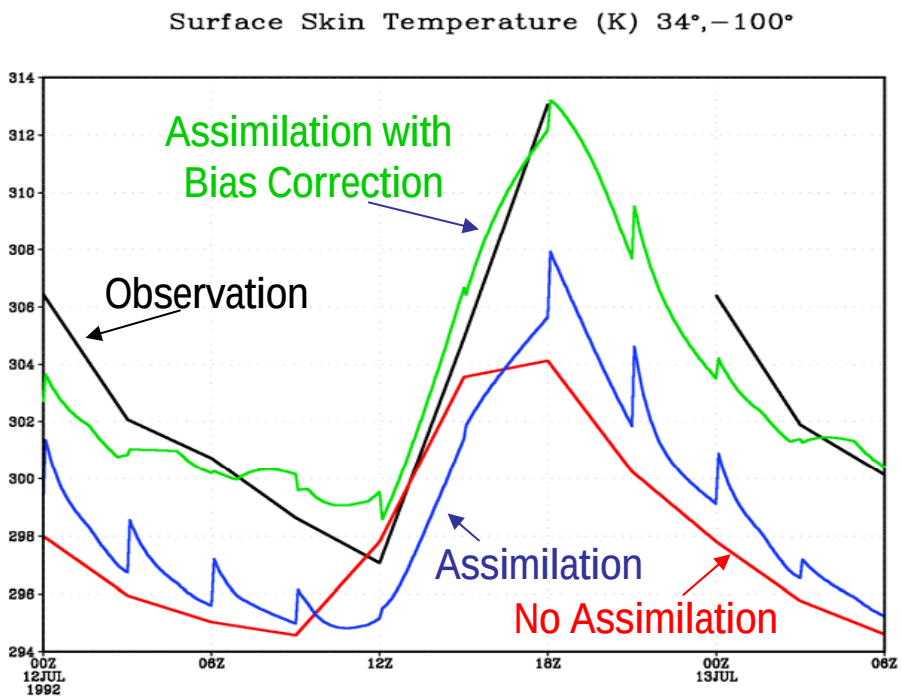
Locations of averaging regions and Cooperative Network snow observation sites

Rodell, M., and P. R. Houser, Updating a land surface model with MODIS derived snow cover, J. Hydromet., 5 (6), 1064-1075, 2004.

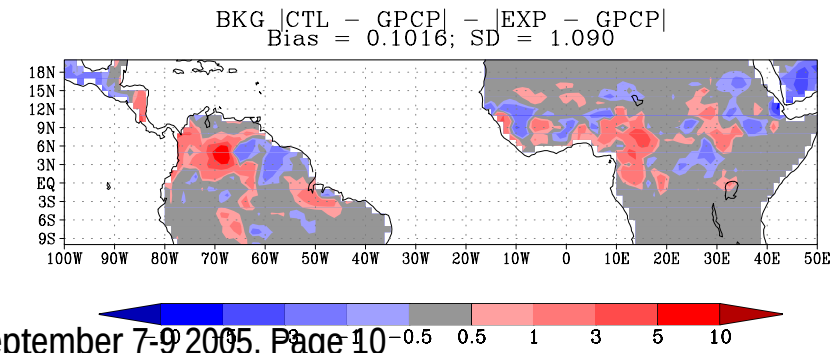
Data Assimilation: Surface Temperature

FVDAS-CLM Assimilation of Remotely-Sensed Surface Skin Temperature



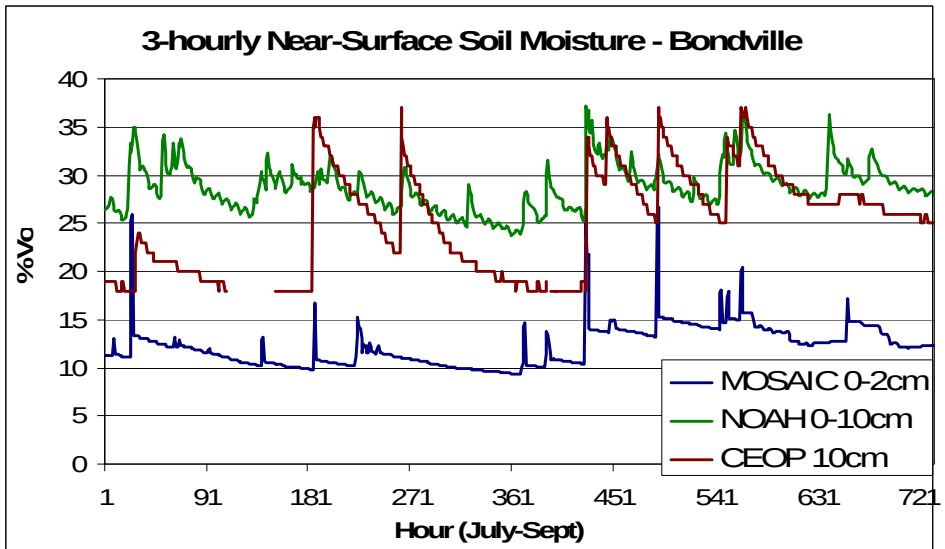


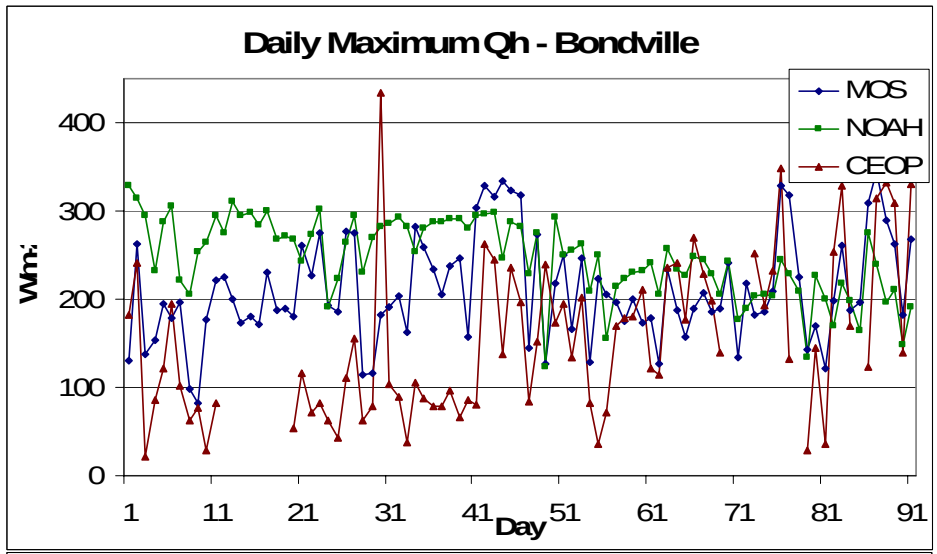
Surface temperature has very little memory or inertia, so without a continuous correction, it tends drift toward the control case very quickly.

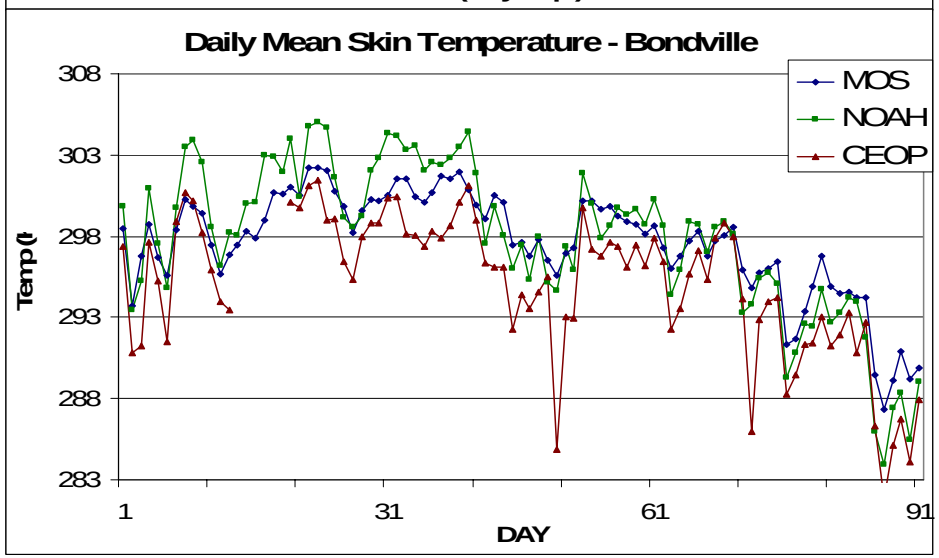


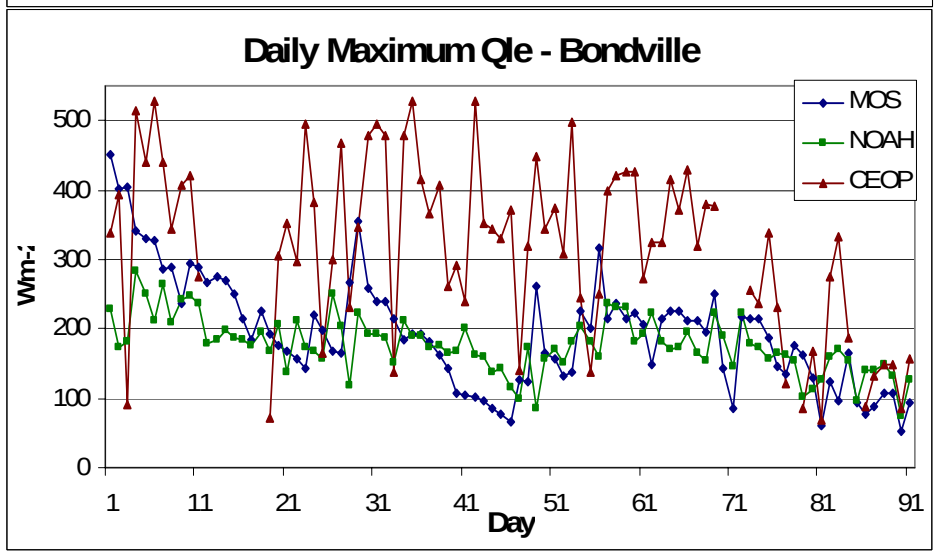
Courtesy of M. Bosilovich (Radakovich et al., 2004)

Output Evaluation: Point Observations



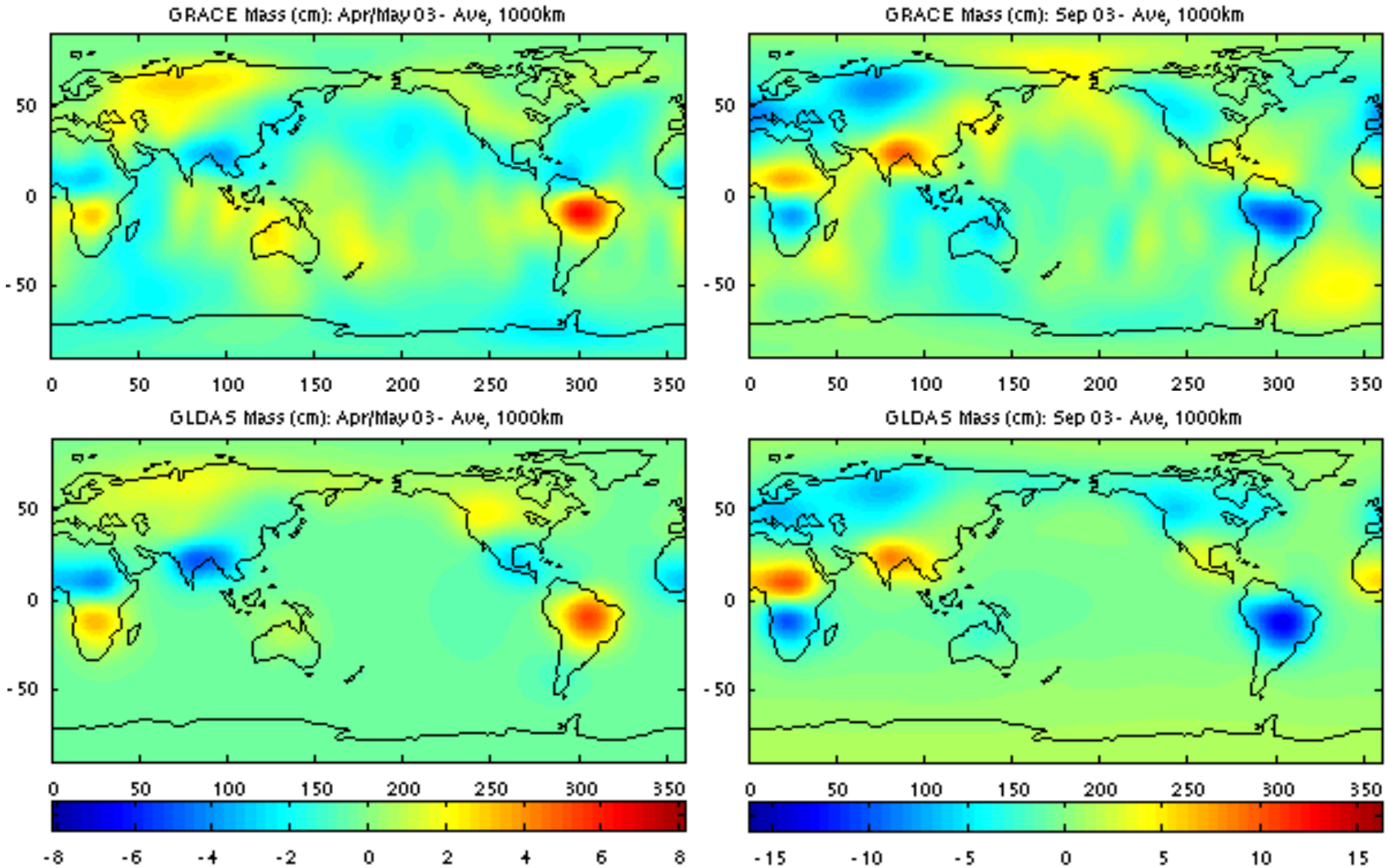






Noah and Mosaic model location time series (MOLTS) and CEOP reference site observations of surface soil moisture, surface temperature, and daily maximum sensible and latent heat fluxes

Output Evaluation: Global Observations



Terrestrial water storage from GRACE (top) and 2m column soil moisture plus snow water equivalent from Noah (bottom), April/May (left) and September (right), 2003 (1000 km smoothing)

Data set needs (particularly large data sets – include potential sizes): All at highest possible resolution

Parameters (static → ~30Gb)

- vegetation class (AVHRR and MODIS based)
- soil fractional sand, silt, clay
- elevation

Forcing (1979 to present and more; multiple brands → ~20Tb)

- total precipitation
- convective precipitation
- downward shortwave radiation
- downward longwave radiation
- near surface air temperature
- near surface specific humidity
- near surface U wind
- near surface V wind
- surface pressure

Data for Assimilation and Evaluation (multiple periods, growing → ~2Tb)

- soil moisture
- snow cover and water equivalent
- surface temperature
- GRACE derived terrestrial water storage changes
- leaf area index
- others?

Project outputs (project results that may be made available to the NEWS team for subsequent use – include potential size/resource requirements):

Output from LIS assimilating land surface models with multiple configurations of models, forcing, resolutions, assimilation, etc. (20-100 Tb depending on number of simulations and res.):

- soil moisture in each layer
- snow depth, fractional coverage, and water equivalent
- plant canopy surface water storage
- soil temperature in each layer
- average surface temperature
- surface and subsurface runoff
- bare soil, snow, and canopy surface evaporation
- canopy transpiration
- latent, sensible, and ground heat flux
- snow phase change heat flux
- snowmelt
- snowfall and rainfall
- net surface shortwave and longwave radiation
- aerodynamic conductance
- canopy conductance
- surface albedo
- vegetation greenness and leaf area index

Potential collaborations (with NSIT, other NEWS projects, etc.) :

Data/Capability Providers:

- Adler (precipitation)
- Sorooshian (precipitation)
- Denning and Lu (Improved CLM model)
- Peters-Lidard (boundary layer coupling to LIS)
- Wielicki (downward radiation)

Product Users:

- Koster (land surface states for forecast model initialization)
- Soden (water and energy cycle research)
- Schubert (drought information)
- Roads (water and energy cycle research)
- Famiglietti (GRACE product assessments)
- Bosilovich (water and energy cycle research)
- Betts (land-atmosphere interaction research)
- Houser (applications)

Important outside linkages/resources (outside the NEWS team) :

- GMAO
- Joint Center for Satellite Data Assimilation
- NOAA/NCEP – Ken Mitchell's group
- Office of Hydrologic Development; USDA; Bureau of Reclamation; other applications programs
- Tom Phillips (LLNL): IPCC Hydrological Assessments

Expected contribution to the NEWS objective:

- Global land surface data and assimilated model output to support studies of the water and energy cycles
- A public tool for integrating multiple datasets
- Based on these, our own assessment of water cycle trends and variability during the past 25-30 years

Issues, needs, and concerns (to be discussed in breakouts, teaming discussions, etc.):

- How to interface with GMAO/MAP research, which has its own, separate land surface modeling component
- How to distribute data and output from our massive archive in an efficient way without laborious reprocessing and reformatting by our group. Converting a large number of datasets (forcing, parameters, output, and otherwise) to NEWS-defined standards for format, resolution, etc., would weigh severely on our manpower and come at the expense of our project goals.